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Predictability effects and parafoveal processing in older readers

Aaron Veldre, Roslyn Wong, and Sally Andrews

School of Psychology, The University of Sydney, NSW, Australia

Author Note

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Correspondence concerning this article should be addressed to Aaron Veldre, School of Psychology, The University of Sydney, NSW 2006, Australia. Email: aaron.veldre@sydney.edu.au

Abstract

Normative aging is accompanied by visual and cognitive changes that impact the systems that are critical for fluent reading. The patterns of eye movements during reading displayed by older adults have been characterized as demonstrating a trade-off between longer forward saccades and more word skipping versus higher rates of regressions back to previously read text. This pattern is assumed to reflect older readers' reliance on top-down contextual information to compensate for reduced uptake of parafoveal information from yet-to-be fixated words. However, the empirical evidence for these assumptions is equivocal. This study investigated the depth of older readers' parafoveal processing as indexed by sensitivity to the contextual plausibility of parafoveal words in both neutral and highly constraining sentence contexts. The eye movements of 65 cognitively intact older adults (61-87 years) were compared with data previously collected from young adults in two sentence reading experiments in which critical target words were replaced by valid, plausible, related, or implausible previews until the reader fixated on the target word location. Older and younger adults showed equivalent plausibility preview benefits on first-pass reading measures of both predictable and unpredictable words. However, older readers did not show the benefit of preview orthographic relatedness that was observed in young adults, and showed significantly attenuated preview validity effects. Taken together, the data suggest that older readers are specifically impaired in the integration of parafoveal and foveal information but do not show deficits in the depth of parafoveal processing. The implications for understanding the effects of aging on reading are discussed.

Keywords

Reading, eye movements, predictability effects, parafoveal processing, aging

Word count: 9,814 (excluding Abstract, References, Footnotes, Tables, and Figures)

Normal aging is associated with declines in measures of fluid cognition, such as processing speed, cognitive control, reasoning, and working memory (see Verhaeghen, 2015, for review). These declines are often assumed to be an inevitable consequence of the deterioration in sensory capacities and changes in neural structure and function that accompany aging (e.g., Hedden & Gabrieli, 2004). But not all cognitive functions decline with age—many aspects of language processing are relatively resilient to age-related deterioration. Older adults report little change in the capacity to use language in everyday life (Light & Burke, 1993) and often show better comprehension of global, situational levels of discourse than younger adults (see Stine-Morrow & Radvansky, 2018, for review). Behavioral measures of semantic priming, lexical processing, and reading skill are also typically sustained or even enhanced in older adults (e.g., Burke & Shafto, 2008; Rawson & Touron, 2015). This is consistent with the well-established psychometric evidence that crystallized abilities such as vocabulary and verbal comprehension remain stable, or increase, until age 70 or 80 (e.g., Schaie, 2005; Uttl, 2002; Verhaeghen, 2003). But it is not clear how differential decline in fluid and crystallized abilities explains the preservation of complex skills like reading.

Successful reading comprehension requires coordination of perceptual, cognitive, and motor systems. Although lower-level processes involved in identifying words may operate automatically in skilled readers (e.g., Kahneman & Treisman, 1984), the processes required to integrate the words in a sentence and retrieve semantic and world knowledge from long-term memory to construct meaning have typically been assumed to depend on fluid abilities such as working memory (e.g., Just & Carpenter, 1992; Kintsch, 1998) that decline with age. Fluent reading also requires precise coordination of attention and oculomotor planning that may be impacted by age-related changes in visual and cognitive systems (e.g., Paterson et al., 2020). The goal of the present research was to use the fine-grained evidence about the time-

course of reading provided by eye movements to investigate whether and how older adults' online reading differs from that of young adults, with a focus on the role of *parafoveal processing*.

Aging and Eye Movements in Reading

During reading, rapid, ballistic eye movements—known as *saccades*—bring information into the high-acuity foveal region of central vision. Saccades are interspersed by brief *fixations*, averaging 200-250 ms, during which visual information is extracted. Information is also processed in the parafoveal region of vision—between 2-5° of visual angle from the point of fixation. Although it was initially assumed that this low-acuity information was used primarily for oculomotor planning, i.e., *where* to move the eyes next, research over the past 40 years has established that readers also initiate linguistic processing in the parafovea (Rayner, 2009).

Older adults' reading typically exhibits both quantitatively and qualitatively different patterns of eye movements to skilled young-adult readers. Healthy older adults read more slowly than younger adults because they make more, and longer, fixations, and more regressions back to previously read text (see Paterson et al., 2020 for review). But, unlike other groups of slow readers, such as children (Blythe, 2014) or low-proficiency adults (e.g., Andrews & Veldre, 2021; Veldre & Andrews, 2014, 2015a, 2015b, 2016a), older readers of alphabetic languages have been reported to show *longer* forward saccades and increased word skipping relative to younger readers (Kliegl et al., 2004; Laubrock et al., 2006; McGowan et al., 2015; Rayner et al., 2006; Rayner et al., 2010). Rayner et al. (2006) attributed this trade-off to older readers' adoption of a *risky-reading strategy* (O'Regan, 1990) in which they use context to “guess” the identity of upcoming words to compensate for declines in visual acuity that limit the extraction of parafoveal information. However, the longer saccades and higher skipping rates claimed to index this strategy have not been

consistently observed in studies of older readers (e.g., Choi et al., 2017; Whitford & Titone, 2017) and appear to depend on task demands (Paterson et al., 2020; Wotschack & Kliegl, 2013). Evidence for Rayner et al.'s (2006) assumptions that older readers show reduced parafoveal processing and stronger reliance on contextual prediction is also inconsistent.

Parafoveal Processing in Reading

Eye-movement studies of parafoveal processing typically use the gaze-contingent *boundary paradigm* in which a target word embedded in a sentence is replaced by a preview stimulus until the reader's eyes cross an invisible boundary at the end of the pre-target word (Rayner, 1975). The *parafoveal preview effect* refers to the shorter fixation durations observed on targets following valid (i.e., identical) relative to invalid (e.g., unrelated word or random letters) previews, which reflect both a benefit from pre-processing information in the valid condition, and a cost from exposure to misleading or orthographically illegal information in the invalid condition (Kliegl et al., 2013). The most widely accepted account of preview effects attributes them to the integration of information across successive fixations. This *trans-saccadic integration* was initially assumed to occur at the level of visual features (Rayner, 1975) but subsequent evidence implicated more abstract codes. In English, robust preview effects are observed for orthographically and phonologically similar previews (see Schotter et al., 2012; Vasilev et al., 2017 for reviews) and extend to morphologically related previews (e.g., Dann et al., 2021). The current consensus view is therefore that parafoveal preview effects arise from integration at the level of abstract codes for word properties such as orthography and phonology (Cutter et al., 2015; Pollatsek et al., 1992).

Preview benefits from semantically similar words were initially interpreted as evidence of trans-saccadic integration of semantic information (e.g., Schotter, 2013; Veldre & Andrews, 2016a). However, these effects were subsequently shown to be modulated by the fit of the preview in the *sentence*, rather than semantic overlap between the preview and the

target (Veldre & Andrews, 2016b). These findings contribute to a body of research that has identified a class of preview effects that cannot be explained by trans-saccadic integration because they do not depend on the relationship between the preview and target (Risse & Kliegl, 2011, 2014; Risse & Seelig, 2019; Schotter & Leininger, 2016; see Andrews & Veldre, 2019, for review).¹ One such phenomenon is the *plausibility preview effect* which describes reduced first-pass fixation duration when the target word replaces an invalid preview that is a plausible continuation of the sentence (i.e., a semantically and/or syntactically acceptable word) versus a preview of a contextually implausible word. For example, in a sentence like ‘*She eventually found a spare **stool** behind the crowded bar*’, Veldre and Andrews (2018a) found a preview benefit for the target word ‘*stool*’ from a contextually appropriate preview like *glass* relative to both a semantically implausible but syntactically appropriate preview like *uncle*, and a preview that was both semantically and syntactically implausible, like *begin*. The plausibility preview effect cannot be attributed to trans-saccadic integration because it occurs for previews that share no orthographic or semantic features with the target word (Veldre & Andrews, 2016b, 2017), so there is no common lexical code to be integrated across fixations. Critically, plausibility preview effects show that words in the parafovea are processed sufficiently deeply to retrieve the semantic and syntactic information required to determine the contextual plausibility of the unfixated preview word rapidly enough to influence early saccadic planning (Veldre et al., 2020).

Previous research on parafoveal processing has been dominated by studies of young adults drawn from college-student populations, with few systematic investigations of older readers. Impairments in older adults’ use of parafoveal and peripheral visual information in non-reading tasks (e.g., Ball et al., 1988; Sekuler et al., 2000) appear to reflect deficits in

¹ In the eye-movement literature, these manipulations have been collectively referred to as *preview difficulty effects* following Risse and Kliegl’s (2014) initial demonstration using a manipulation of the word frequency of the preview, which attributed them to the differential difficulty of processing high and low frequency previews.

extrafoveal visual acuity. For example, the average visual span of older adults has been found to be approximately 1.2 characters smaller than that of young adults, suggesting that sensory limitations contribute to age differences in the uptake of parafoveal information during reading (Warrington et al., 2019). This is consistent with evidence that older adults are relatively less impaired than young adults in reading ‘filtered’ text for which only low spatial-frequency information is available, and relatively more impaired when only high spatial-frequency information is available (Jordan et al., 2014; Paterson et al., 2013). Older adults are also more disrupted than young adults by the removal of inter-word spaces from text, suggesting that they rely more on the low spatial frequency information provided by word spaces to target saccades (McGowan et al., 2014; Rayner et al., 2013).

More direct evidence about the extent of parafoveal processing derives from applications of the *moving-window paradigm* (McConkie & Rayner, 1975) to assess age-related differences in the perceptual span—the region of text from which information is extracted during a single fixation in reading. By systematically varying the size of a window of visible text around the reader’s point of fixation, many studies have shown that young-adult readers of English require approximately 3-4 letters to the left and up to 14-15 letters, or about 3 words, to the right to maintain reading fluency (see Rayner, 2014, for review). In contrast, Rayner et al. (2009) observed that older adults showed no additional benefit from window sizes larger than one word to the right of fixation, and were more disrupted than younger readers by being deprived of one word to the left. Veldre et al. (2021) recently confirmed the increased leftward extent of the perceptual span among older readers and showed that the size of the rightward span depended on written language proficiency. These findings suggest that older readers have a smaller and less asymmetric perceptual span than younger readers. Consistent with this interpretation, Rayner et al. (2014) found that older adults were more disrupted by reading text in which the foveal word was masked in a gaze-

contingent fashion compared to a condition in which all rightward text was masked, suggesting that they rely more on foveal than parafoveal information.

Using the boundary paradigm, Rayner et al. (2010) found that, compared to younger adults, older adults showed a smaller preview effect from a valid preview versus a random-letter baseline. This effect was specifically due to increased refixations on the target following an invalid preview among young but not older readers, suggesting that older readers showed less preview cost. A similar time-course was observed by Payne and Stine-Morrow (2012) who compared preview effects for targets following words at sentence-internal, clause-final, or sentence-final positions. Younger and older readers showed similar preview effects relative to a random-letter baseline on early first-pass measures and similar reductions in the size of the preview effect across clause boundaries. However, on later measures that included refixations and regressions, older readers showed a smaller preview effect across sentence boundaries than younger readers. Thus, older readers only showed reduced parafoveal processing in association with the cognitively demanding integration processes associated with sentence ‘wrap-up’ (Just & Carpenter, 1980). Payne and Stine-Morrow interpreted this selective effect as suggesting that parafoveal processing remains intact with age, and that age differences in the preview effect may be specific to cognitively demanding integrative processing. Consistent with this interpretation, Risse and Kliegl (2011) found no age difference in the preview effect from word_{N+2} during first-pass reading, suggesting that the extent of parafoveal processing does not decline with age.

To date, all boundary-paradigm studies of age differences in parafoveal processing have examined trans-saccadic preview benefits by comparing a valid condition, that involves no display change, to an invalid, display-change condition. The only type of invalid preview that has been used is an orthographically illegal string, raising the possibility that age differences in parafoveal processing are specific to such conditions. No studies have

examined the effect of aging on the plausibility preview effects described above. If older adults' reduced sensitivity to preview validity reflects a general impairment in parafoveal processing (Rayner et al., 2010), age differences should also be observed in the preview plausibility effect which depends on deep parafoveal processing.

Aging and Predictability Effects during Reading

According to the risky reader account (Rayner et al., 2006), older readers compensate for declines in parafoveal processing by capitalizing on their preserved crystallized knowledge to “guess” the identity of upcoming words. If so, they should show larger effects of a word's contextual predictability—as indexed by cloze probability (Taylor, 1953)—on both skipping and early fixation duration measures compared to younger readers. However, the empirical evidence on this issue is contradictory.

Rayner et al. (2006) found that, although older readers showed larger frequency effects and higher overall rates of target-word skipping than younger readers, predictability effects on both skipping and fixation duration measures were not significantly modulated by age. In contrast, Kliegl et al.'s (2004) analysis of corpus data found that predictability effects on word skipping were larger for younger than older readers, while only older readers showed a reduced probability of making multiple fixations on high predictability words. However, Whitford and Titone's (2017) corpus analysis of paragraph reading in bilinguals found that the only difference in predictability effects was that older readers showed greater cost than young readers on the late measure of total duration for low predictability words. Finally, Steen-Baker et al.'s (2017) study of readers aged between 16 and 64, found greater facilitation for high predictability words among older readers on go-past duration—a late measure of first-pass reading that indexes reanalysis.

To our knowledge, only one study has investigated whether contextual predictability modulates eye-movement indices of parafoveal processing among older readers. Choi et al.

(2017) compared target words that were either the most predictable continuation of a high-constraint sentence (e.g., *liver* in the sentence “*The doctor told Fred that his drinking would damage his...*”, or an unpredictable but plausible continuation (e.g., *heart*). To assess the precision of the information extracted from the parafovea, valid previews were compared with invalid nonword previews that were orthographically similar to the word in the other predictability condition (e.g., *heant* as a preview for *liver* and *livor* for *heart*). Unexpectedly, predictability did not affect skipping rates in either younger or older readers, but both age groups skipped validly previewed target words more than targets preceded by a nonword preview, even when it was similar to the expected target word, suggesting that they had extracted precise letter-identity information from the parafovea. Older adults showed larger predictability effects than younger readers on late fixation-duration measures, but only in valid preview conditions. Choi et al.’s design could not distinguish whether this reflected enhanced benefit for predictable targets or greater cost for unpredictable targets, but they interpreted their findings as indicating that older readers make more use of contextual information to facilitate word identification than younger readers, perhaps to compensate for reduced visual acuity in the parafovea. However, rather than demonstrating a risky guessing strategy, older readers effectively combined “top-down information from the sentence context with bottom-up input from the parafovea to optimize processing” (Choi et al., 2017, p. 239).

Thus, the eye-movement literature provides little evidence that older readers are more likely to skip highly predictable words, as expected if they rely more on guessing of upcoming words than younger readers. This is consistent with the conclusion drawn from research applying event-related potential (ERP) methods that “during normal sentence processing, older adults do not routinely engage in predictive comprehension to the degree that young adults do” (Wlotko et al., 2012, p. 986). The N400 component of the ERP

waveform, a well-established index of sensitivity to contextual predictability (Kutas & Hillyard, 1984), is significantly reduced and delayed in older readers, particularly for more weakly constrained contexts (see Wlotko et al., 2010 for a review). Older readers also differ from young readers in a late frontal component that occurs after the N400 for plausible, but unexpected, continuations. This component is thought to reflect semantic revision and updating processes triggered by an incorrect prediction, so the finding that it is reduced or absent in older readers is taken as further evidence of their reduced reliance on prediction (Federmeier et al., 2010; Wlotko et al., 2012). Older adults' failure to engage predictive mechanisms is attributed to slower, less efficient incremental integration of sentence context, which reduces their capacity to generate predictions.

However, there are reasons to question the generality of these findings to naturalistic reading because most ERP studies of sentence reading employ a rapid serial visual presentation (RSVP) format in which the words of the sentence are presented one-by-one in the center of the screen, usually at a fixed rate that is substantially slower (400-500 ms/word) than the average reading speed of even older adults. As well as potentially increasing the cognitive demands of integrating the words of the sentence, this format deprives readers of the opportunity to either regress to earlier words, or to extract parafoveal information from upcoming words.

To address the limitations of the single-word RSVP format, Payne and Federmeier (2017) used the *RSVP-with-flankers* paradigm (Barber et al., 2010) in which the central target word is flanked to the left and right by the preceding and upcoming words of the sentence, respectively, to compare older and younger adults' N400 responses to parafoveal and foveal targets varying in cloze probability. Young adults showed graded N400 effects of predictability when the target was in the parafovea, but these effects were greatly attenuated when the target subsequently appeared in the fovea. Interestingly, older adults showed the

same pattern and magnitude of graded N400 effects to parafoveal targets as young adults, suggesting no age-related declines in the depth of parafoveal semantic processing. However, unlike young adults, older adults also showed graded predictability effects on N400 when the target re-appeared in foveal vision. This was interpreted as evidence that older readers fail to effectively integrate parafoveal and foveal information, and therefore do not show benefits of parafoveal pre-activation of semantic information on foveal word identification.

It remains unclear, however, whether the specific deficit in parafoveal-foveal integration observed by Payne and Federmeier (2017) extends to trans-saccadic integration during natural reading because the RSVP paradigm precludes readers from making eye movements. These artificial conditions may disrupt the coordination of cognitive and oculomotor processes that older adults have developed over decades of reading experience to compensate for gradual declines in sensory and cognitive capacities. Further evidence obtained in the more naturalistic reading context provided by eye-movement recording is required to determine how age modulates readers' integration of bottom-up and top-down information during online reading.

The Present Research

The two experiments reported here used the plausibility preview effect to investigate whether aging modulates the depth of parafoveal processing and/or the incremental integration of sentence context that is required to assess the contextual fit of upcoming words. Evidence that the plausibility of a parafoveal preview affects early measures of reading the target word means that readers must have (i) effectively integrated the preceding context and (ii) completed lexical, semantic, and post-lexical processing of the parafoveal preview rapidly enough to influence saccadic planning (Veldre et al., 2020). Thus, evidence of plausibility preview effects in older readers would be incompatible with the conclusion that they do not engage in deep parafoveal processing. This is the focus of Experiment 1 which used a design

tested in young adults by Veldre and Andrews (2017). Experiment 2 used materials presented to young adults by Veldre and Andrews (2018b) which combined an independent test of the plausibility preview effect with assessment of the effect of predictability on both parafoveal and foveal processing in older adults.

General Method

Participants

Sixty-five healthy, cognitively intact older adults ($M = 71.6$ years of age; range: 61-87 years; 40 female) who were living independently in the community participated in the study in return for cash reimbursement.² Most participants (80%) had completed some form of post-secondary education (technical/vocational training or university) and 68% had a college degree. All participants reported that English was the first language that they learned to read and write and were assessed to have corrected visual acuity at the experimental viewing distance that was within the normal range (greater than 20/35). Participants completed both experiments in a single session and were compared with the young-adult samples from the two corresponding published studies: Veldre and Andrews (2017; $n=78$; $M_{\text{age}}=19.50$ years)³ and Veldre and Andrews (2018b; $n=95$; $M_{\text{age}}=19.00$ years).

The older adults completed a test battery that was also administered to the young adults from Experiment 2 (Veldre & Andrews, 2018b) including a half-timed version of the Nelson-Denny Reading Test (Brown et al., 1993), which comprises measures of vocabulary, reading comprehension, and reading rate; and two tests of spelling ability—spelling dictation, and spelling recognition (see Andrews et al., 2020 for spelling instruments and comparison of

² The data for two additional participants were excluded because a technical error prematurely terminated the experiment.

³ The analyses included the data from Veldre and Andrews' (2017) Experiment 1A and 1B. In addition to reading for comprehension, Experiment 1A required participants to complete a secondary animal-word detection task. However, this additional task requirement had minimal impact on first-pass reading measures or the pattern of preview effects so the data from both experiments were combined to maximize statistical power.

half versus full-timed administration of the Nelson-Denny Reading Test). The younger adults in Experiment 1 did not complete this test battery but were drawn from the same undergraduate student population as the participants in Experiment 2. As summarized in Table 1, the older adults had significantly higher vocabulary scores than the young adults, consistent with previous evidence of a vocabulary advantage in older adulthood (e.g., Ben-David et al., 2015; Keuleers et al. 2015). Older adults' spelling scores were also higher than the younger adults, but the two groups did not differ significantly on either reading comprehension or reading rate. All older participants also performed within the normal range for their age and education level on the Brief Intellectual Ability scale of the Woodcock-Johnson III (Woodcock et al., 2001, 2007) and tests of phonemic and semantic verbal fluency.

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Materials

The critical stimuli were 160 sentences ($M=13.6$ words), comprising the materials of both Experiments 1 and 2 (80 sentences in each experiment; see details below and Veldre & Andrews, 2017, 2018b for stimulus characteristics and norming), in which the preview of a 4-8 letter target word was manipulated prior to the reader making a saccade across an invisible boundary at the end of the pre-target word ($M=5.5$ letters). The materials for the two experiments were intermixed and presented in an individually randomized order.

Apparatus and Procedure

Eye movements were recorded by an Eyelink 1000+ as participants read sentences on a 21-in CRT monitor with a refresh rate of 140 Hz. The sentences occupied a single line and were presented in black monospaced font on a gray background. Viewing was binocular but

fixation position was monitored from the right eye.⁴ Chin and forehead rests minimized head movements. At the 60 cm viewing distance, 2.5 characters subtended 1° of visual angle.

The experiment began with a 3-point calibration procedure followed by three practice trials. On each trial, a fixation point occupied the location of the first letter of the sentence. When a stable fixation was detected on this point, the sentence was displayed, or a new calibration procedure was performed if necessary. Mean calibration error was less than 0.3° of visual angle. Participants were instructed to read the sentences for meaning. On approximately 30% of trials, a multiple-choice comprehension question was displayed that required understanding of the meaning of the sentence and could not be answered by lexical verification alone. The experimental materials were divided into two blocks and separated by the battery of individual-differences measures. Latin-square counterbalancing ensured that all sentences appeared in all preview conditions across participants. The study was approved by The University of Sydney Human Research Ethics Committee.

Global Reading Analyses

Prior to analysis, fixations below 80 ms that were within one letter space of an adjacent fixation were merged with that fixation (0.4% of fixations). Trials were discarded if there was a blink immediately before or after a fixation on the target (5.04% of trials) or if the display change completed more than 10 ms into a fixation or was triggered by a saccade that ultimately landed to the left of the boundary (i.e., “j-hooks”; 13.91% of trials). Target fixations below 80 ms or above 1000 ms, gaze and go-past durations above 2000 ms, and total durations above 4000 ms were also excluded (0.7% of trials). These exclusions left 4317 trials (83.02% of the data) and 4307 trials (82.83%) available for analysis in Experiment 1 and 2, respectively. The same procedures applied to the young-adult data resulted in 5240 trials (83.97%) and 6727 trials (88.51%) in Experiment 1 and 2, respectively.

⁴ For two participants the left eye was tracked because a stable calibration was not possible for the right eye.

The first set of analyses compared the older adults' data with the combined datasets of young adults reading the Experiment 1 and 2 materials ($n=173$) on several global reading measures based on the whole sentence: total sentence reading time, forward saccade length, average fixation duration, number of fixations, and number of regressions. The means for these measures for each group are reported in Table 2.

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The data were analyzed by linear mixed-effects models (LMM) using the *lme4* package (Version 1.1-21; Bates et al., 2015) in *R* (Version 3.5.3; R Core Team, 2019). The models included the fixed effect of age (older vs. younger), random intercepts for subjects and items, and a by-item random slope for the age effect. Estimates yielding t values greater than $|1.96|$ were interpreted as significant at the .05 alpha level.

Compared to younger readers, older adults read more slowly overall than younger readers, resulting in significantly longer total sentence reading times [$b=731.00$, $SE=244.10$, $t=3.00$]. However, this was principally due to increased rereading from a significantly higher number of regressions [$b=0.85$, $SE=0.29$, $t=2.92$] rather than slower first-pass reading because younger and older readers did not differ significantly in either number of fixations [$t<1$] or average fixation duration [$b=-6.32$, $SE=3.91$, $t=-1.62$]. Consistent with previous eye-movement studies (Paterson et al., 2020), older adults made longer forward saccades than younger readers (approximately half a letter space, on average) [$b=0.51$, $SE=0.22$, $t=2.37$].

Such age differences in global reading behavior have been attributed to older adults' adoption of a contextually based reading strategy (Rayner et al., 2006). The analyses of local reading measures on the target word reported below directly assessed older adults' parafoveal processing of predictable and unpredictable words.

Experiment 1

Experiment 1 factorially manipulated the orthographic relatedness of the preview to the target word and the plausibility of the preview in the sentence. This design allows comparison of the classical effects of preview validity and orthographic overlap that have been attributed to trans-saccadic integration with the plausibility preview effect, where such integration is not possible because the preview and target are not orthographically or semantically related. Veldre and Andrews (2017) found that young adults showed additive benefits of preview plausibility and preview-target orthographic relatedness, suggesting that the effects arise from two independent mechanisms. If older readers engage in shallower parafoveal processing than younger readers, due to reduced lexical processing speed or poorer visual acuity, they should show reduced identical and orthographic preview effects and be insensitive to preview plausibility because this effect requires deep parafoveal processing.

Experiment 1 compared five preview conditions (see Figure 1): (1) *Valid*: identical to the target; (2) *Plausible Neighbor*: acceptable continuation of the sentence differing from the target by a single non-initial letter; (3) *Implausible Neighbor*: word neighbor of the target that was semantically and/or syntactically unacceptable given the prior context; (4) *Plausible Unrelated*: acceptable sentence continuation that was orthographically unrelated to the target; or (5) *Implausible Unrelated*: implausible sentence continuation that was orthographically unrelated to the target. Cloze norming confirmed that the targets and previews were not predictable from the sentence context (all <1% mean cloze probability; see Veldre & Andrews, 2017).

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Results

Older adults' mean comprehension accuracy was high ($M=91.07\%$; *Range*: 72-100%), but significantly below that of the young-adult group ($M=96.11\%$; $t(141)=5.61$, $p<.001$).

The following target reading measures were analyzed: *first-fixation duration* (duration of the first fixation regardless of the number of fixations on the target), *single-fixation duration* (fixation duration when only one first-pass fixation was made), *gaze duration* (sum of all first-pass fixations), *go-past duration* (sum of all fixations from the first fixation on the target until a word to the right was fixated, including regressions to words earlier in the sentence), and *total duration* (duration of all fixations including first-pass fixations and any regressions from later in the sentence). Measures of the probability of *skipping* the target; the probability of *regressions-out* to words earlier in the sentence; and *regressions-in* from words later in the sentence were also analyzed. Means for each measure for the older readers are provided in Table S1. Figure 2 contrasts the means for both age groups on skipping—a measure that has been shown to differ between older and younger readers in previous studies—and a representative measure of first-pass reading of the target word—single fixation duration. Plots of the other measures that showed significant Age $\times$ Preview interactions are included in Figure S1.

Four planned contrasts were tested: (i) *Valid* preview effect: valid preview versus average of the invalid previews; (ii) *Plausibility* preview effect: average of the two (invalid) plausible versus average of the two implausible previews; (iii) *Orthographic relatedness* preview effect: average of the two related versus average of the two unrelated previews; and (iv) *Plausibility $\times$ Orthographic relatedness* interaction. Age (effect coded: older versus younger) was tested as a fixed effect, as well as interactions between age and the preview contrasts. The models included by-subject and by-item random intercepts and slopes for the preview contrasts, and a by-item random slope for the age effect. Model summaries of the analyses of the combined data and older adults' data are provided in Table S2 and S3, respectively. Power analyses conducted with 100 Monte Carlo simulations using the *simR* package (Green & MacLeod, 2016) demonstrated adequate power ($>.87$) to detect Age $\times$

Preview interactions of at least the effect size reported by Payne and Stine-Morrow (2012; 20 ms on first-fixation duration and 23 ms on gaze duration).

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Main Effects of Age

As depicted in Figure 2 (upper panels), overall target word skipping was significantly higher for older than younger readers [26.47 vs. 19.60%; $z=2.87$]. There were no main effects of age on first-pass measures, i.e., first-fixation, single-fixation, and gaze duration [all $|t|s < 1.23$], or on total duration [$t=-1.00$], but older readers had longer go-past durations [387 vs. 355 ms; $t=2.22$] and higher regressions-out [20.48 vs. 15.58%; $z=2.42$]. In contrast, regressions-in to the target word were higher for *younger* than older readers [38.09 vs. 25.97%; $z=-3.44$].

Thus, consistent with the global reading analyses and the findings of many previous studies of older adults' eye movements, older readers were more likely than younger readers to skip the target but showed longer go-past times, an index of early reanalysis.

Valid Preview Effect

There was a significant *valid preview effect* across all duration measures [all $|t|s > 6.16$]. Relative to an invalid preview, skipping was significantly higher [$z=2.17$], and both regressions-out [$z=-3.91$] and regressions-in [$z=-2.83$] were significantly lower in the valid preview condition.

Aging effects. There was a significant Age $\times$ Valid preview interaction on skipping [$z=-2.50$], single-fixation duration [$t=2.21$], go-past duration [$t=2.52$], and regressions-out [$z=2.82$]. As illustrated for skipping and single-fixation duration in Figure 2, the valid preview effect (valid versus invalid previews) was larger for younger than older readers. The separate analyses of the older adult data reported in Table S3 showed significant validity effects on all duration measures [$ts > 3.07$], albeit significantly smaller than those of young

adults on single-fixation duration and go-past duration. However, unlike young adults, older adults' skipping and regressions-out were not significantly affected by preview validity [both $t_s < 1.14$]. The Age $\times$ Valid preview interaction did not reach significance on the remaining measures [t_s and $z_s < 1.86$].

Orthographic Relatedness Preview Effect

The effect of *preview orthographic relatedness* was significant across all first-pass duration measures [all $|t|s > 3.11$]. Relative to an orthographically unrelated preview, target reading time was shorter following a neighbor preview. Regressions-out were also significantly lower following a related than an unrelated preview [$z = -2.43$]. Preview relatedness did not significantly affect any other measure [all $|t|s$ and $|z|s < 1.68$].

Aging effects. The Age $\times$ Orthographic relatedness interaction was significant on first-fixation duration [$t = 2.22$], single-fixation duration [$t = 2.76$], go-past duration [$t = 2.98$], and regressions-out [$z = 2.96$], but did not reach significance on the remaining measures [t_s and $z_s < 1.59$]. The age interactions indicated that the orthographic relatedness preview effect was restricted to young readers for all first-pass measures except gaze duration (compare neighbor and unrelated previews for younger and older readers in Figure 2; lower panels).

Plausibility Preview Effect

Skipping was significantly higher for a plausible preview than an implausible word [$z = 3.89$]. The *plausibility preview effect* was significant on all first-pass duration measures reflecting shorter reading times after plausible versus implausible previews [all $|t|s > 3.41$]. There was no plausibility preview effect on total duration [$t < 1$] or regressions-out [$z = -1.83$], and regressions-in were significantly *higher* when the preview was a plausible word than when it was implausible [$z = 5.37$]. Thus, the plausibility preview effect was restricted to first-pass reading because it was counteracted by later re-reading of targets preceded by plausible invalid previews. This trade-off between an early cost from postlexical integration difficulty

caused by processing an implausible word and a later cost arising from the discrepancy between the plausible preview and the target has been observed in a number of studies (see Andrews & Veldre, 2019).

Aging effects. In contrast to the age differences in the preview validity and orthographic relatedness effects, the Age $\times$ Plausibility preview interaction was not significant on any measure [all $|t|$ s and $|z|$ s < 1.59]. As can be seen in Figure 2 (lower panels), averaged over preview relatedness, younger and older readers showed a similarly sized benefit from a plausible preview versus an implausible preview on first-pass reading. Paralleling the young-adult data, separate analyses of the older adults' data showed that the early benefit for plausible previews was counteracted by higher regressions-in following plausible versus implausible previews (see Table S3). The plausibility preview effect was not observed on total duration for either age group.

Plausibility $\times$ Relatedness Preview Effect

Finally, there was a significant *Plausibility $\times$ Relatedness* interaction on skipping [$z = -3.04$] reflecting a stronger plausibility effect for orthographically unrelated previews than for orthographic neighbors.

Aging effects. The separate group analyses showed that the Plausibility $\times$ Relatedness interaction on skipping was only significant for older adults (cf. Table S3; Veldre & Andrews, 2017). However, the Age $\times$ Plausibility $\times$ Relatedness interaction was not significant on any measure [all $|t|$ s and $|z|$ s < 1.17].

Discussion

Despite their slower global reading, older adults showed a robust plausibility preview effect on first-pass measures of target-word processing that was of equivalent magnitude to that shown by younger readers. In contrast to the lack of age differences in the plausibility preview effect, the preview benefit from both valid and orthographically related previews

was significantly smaller for older than younger readers across several reading measures. This reduction in orthographic preview benefits is consistent with previous investigations of these ‘classical’ indices of trans-saccadic integration (e.g., Rayner et al., 2010) which have been interpreted as demonstrating an age-related impairment in parafoveal processing. However, plausibility preview effects require sufficiently deep parafoveal processing to retrieve semantic and syntactic features and determine their fit with the developing sentence representation (Veldre et al., 2020). The finding of preserved plausibility preview effects appears incompatible with the view that older readers extract less information from the parafovea than younger readers and therefore rely more on contextual prediction.

However, the low predictability of the targets and previews used in Experiment 1 may have discouraged reliance on sentence context. Experiment 2 compared parafoveal processing of plausible and implausible words embedded in constraining contexts to directly probe age differences in reliance on contextual predictability.

Experiment 2

Experiment 2 used sentences that were constructed to be highly constraining towards one word (e.g., *The lawyer feared his client was probably....*). The target was either the highest cloze *predictable* word (e.g., *guilty*; mean cloze=70%, range: 40-100%), or a matched plausible but *unpredictable* word (e.g., *insane*; mean cloze=1%, range: 0-15%). Prior to the reader crossing the invisible boundary, the parafoveal preview of the target word was either valid (i.e., an identical preview of either the predictable or unpredictable word), plausible (i.e., the unpredictable word *insane* as a preview for the predictable target *guilty* or vice versa), or an implausible unrelated word (e.g., *mirror*) to provide a baseline to assess the effect of plausibility. An additional contextually implausible but semantically related preview condition (e.g., *courts*) was included to allow effects of contextual plausibility to be distinguished from any benefit due to lexical/semantic association (see Figure 3).

Veldre and Andrews' (2018b) critical finding for young adults was that target predictability interacted with preview type, reflecting larger preview validity and plausibility effects when the preview was the predictable word. Importantly, however, there was a significant plausibility preview effect on first-pass reading when the preview was an unpredictable word relative to an unrelated or semantically related implausible word. That is, readers benefited from previewing a plausible word relative to an implausible word even when the context strongly constrained towards a different, orthographically unrelated word.

Thus, as well as providing an independent replication of older readers' sensitivity to preview plausibility, Experiment 2 directly tested whether older adults relied more on context, and whether predictability modulated the depth of parafoveal processing.

--- INSERT FIGURE 3 HERE ---

Results

Average comprehension accuracy among older adults was high ($M=91.10\%$; *Range*: 78-100%) but significantly lower than that of younger adults ($M=96.48\%$; $t(158)=6.56$, $p<.001$).

(G)LMMs tested the fixed effects of target predictability (effect-coded), preview, and interactions between target predictability and preview. Three preview contrasts were tested: (i) *Valid* preview effect – valid versus plausible; (ii) *Plausibility* preview effect –plausible versus average of implausible related and implausible unrelated; (iii) *Related* preview effect – implausible related versus implausible unrelated. Age (effect coded: older versus younger) was tested as a fixed effect, along with the two-way interactions involving age, predictability, and preview. Power analyses conducted with 100 Monte Carlo simulations using the *simR* package demonstrated that the sample size provided adequate power ($>.86$) to detect Age $\times$ Predictability interactions of the size reported by Choi et al. (2017; 10 ms on first-fixation duration; 17 ms on gaze duration) and Age $\times$ Preview interactions of 15 ms on first-fixation

duration and 18 ms on gaze duration (cf. 20 and 23 ms, respectively, reported by Payne and Stine-Morrow, 2012). There was insufficient power to test the three-way interactions between age, predictability, and preview so these higher order interaction terms were excluded from the final models. However, models including the three-way interactions yielded the same pattern of significant effects. The models included by-subject and by-item random intercepts and slopes for predictability and preview, and a by-item random slope for the age effect.

Means for each reading measure for the older readers are shown in Table S4.

(G)LMM summaries for analyses of the combined data and the older adults' data are shown in Tables S5 and S6, respectively. As for Experiment 1, means for both age groups are plotted for skipping and single-fixation duration in Figure 4. Figures 5 and 6 depict the significant interactions involving age observed on other measures.

--- INSERT FIGURE 4 HERE ---

Skipping

The skipping GLMM tested only the fixed effect of preview averaged over target predictability (i.e., predictable preview; unpredictable preview; implausible related preview; implausible unrelated preview) because skipping occurs before the display change and therefore before the target word has been presented. Skipping was higher for predictable previews than unpredictable previews [$z=3.37$]. Skipping was also significantly higher for plausible words (predictable or unpredictable) than implausible words (related or unrelated) [$z=6.27$]. However, skipping did not differ significantly for implausible related and implausible unrelated previews [$z<1$]. Thus, skipping was primarily affected by whether the upcoming word was a contextually plausible continuation of the sentence.

Aging effects. As illustrated in the upper panels of Figure 4, overall skipping of the target word was significantly higher among older than younger readers [$z=3.20$]. Older adults' skipping was less affected by preview condition than younger readers, reflected by a

significant interaction between age and the difference between plausible and implausible previews [$z=-2.02$]. However, like younger readers, the separate analysis of the older adults' data showed a significant plausibility effect on skipping (see Table S6).

Fixation Duration Measures

Target word predictability. There was a significant main effect of target word predictability on go-past duration and total duration [$ts>2.83$] reflecting shorter reading times for predictable than unpredictable targets. Regressions-in were also significantly lower for predictable words than unpredictable words [$z=2.18$]. While the predictability of the target word did not affect early duration measures [i.e., first-fixation, single-fixation, and gaze duration; $ts<1.32$], significant interactions with preview condition reported below indicate that this was because readers were sensitive to the predictability of the *preview* word.

Aging effects. The Age $\times$ Target predictability interaction was significant on first-fixation duration [$t=2.03$], go-past duration [$t=2.28$], and regressions-out [$z=2.56$]. Regressions-in showed a significant effect of age [$z=-2.20$], which was qualified by a significant Age $\times$ Target predictability interaction [$z=2.51$]. Figure 5, which presents the predictability effect averaged over preview condition, shows that these interactions reflected larger effects of target predictability for older than younger readers.

--- INSERT FIGURE 5 HERE ---

Valid preview effect. The preview validity effect was significant on all fixation duration measures [$|t|s>2.13$]. This was qualified by a significant Predictability $\times$ Valid preview interaction on all reading measures [$|t|s>4.59$]: Reading times were longer for plausible (invalid) than valid previews when the target was predictable, but for unpredictable targets reading times were *shorter* for plausible (invalid) than valid previews. Thus, readers showed a *reversed preview effect* (i.e., longer reading times for a valid preview than for an invalid plausible preview; Schotter & Leininger, 2016) when the invalid preview was a more

predictable continuation of the sentence than the valid preview. Regressions-in were also significantly lower following a valid versus plausible preview [$z=-5.74$].

Aging effects. The Age $\times$ Valid preview interaction was significant on all fixation duration measures [$|t|s>2.17$]. As can be seen in Figure 6, these interactions indicated that, averaged over predictability, the benefit from valid relative to plausible previews was significantly smaller for older than younger readers. This reduced sensitivity to preview validity extended across all reading measures and, consistent with Rayner et al. (2010), was principally due to less cost from processing an invalid preview. However, consistent with prior findings (e.g., Balota et al., 1985) preview effects depended on the predictability of the preview/target: both age groups showed both larger preview validity effects for predictable versus unpredictable targets (see Table S6).

--- INSERT FIGURE 6 HERE ---

Plausibility preview effect. The plausibility preview effect was significant across all first-pass measures [$|t|s>7.12$]. This was qualified by a significant Predictability $\times$ Plausibility preview interaction [$|t|s>3.52$], which reflected a larger plausibility preview effect when the target was *unpredictable* (i.e., when the plausible preview was a predictable word). Follow-up analyses confirmed that when the target was predictable, and the plausible preview was therefore an unpredictable word, there was still a significant plausibility preview effect on first-pass measures [$|t|s>2.38$]. As in Experiment 1, the plausibility preview effect was not significant on total duration [$t<1$] and regressions-in were significantly *higher* in the plausible preview condition [$z=4.03$]. Thus, the plausibility preview effect was restricted to first-pass reading of the target word and was stronger for predictable previews than unpredictable previews. However, the early benefit from previewing a plausible, but invalid, word was counteracted by later rereading of the target word.

Aging effects. As in Experiment 1, the Age $\times$ Plausibility preview interaction was not significant on any measure [all $|t|$ s and $|z|$ s < 1.25]. As shown in the lower panels of Figure 4, the magnitude of the plausibility preview effect was similar for older and younger readers. Like younger readers, older adults showed larger plausibility preview effects for unpredictable targets, reflecting facilitated parafoveal processing of a contextually predictable word (see Table S6).

Contextual relatedness preview effect. The small benefit from an implausible related preview over an implausible unrelated preview reached significance on single-fixation duration [$t = -2.14$] and regressions-in [$z = 2.18$], but was not significant on any other measure [$|t|$ s and $|z|$ s < 1.46]. This effect did not significantly interact with target predictability [all $|t|$ s and $|z|$ s < 1.25].

Aging effects. The Age $\times$ Related preview interaction was not significant on any measure [all $|t|$ s and $|z|$ s < 1.74].

Discussion

As observed in Experiment 1, older adults showed a reduced preview validity effect relative to younger readers. However, this does not appear to reflect a general impairment in parafoveal processing because age did not modulate the effects of preview plausibility. Older adults showed robust plausibility preview effects, which imply that they had successfully integrated the earlier sentence context and processed the parafoveal previews sufficiently deeply to extract the semantic and syntactic features required to detect their contextual plausibility. These findings add to those of Experiment 1 by showing that older adults' plausibility preview effects extended to sentences that strongly constrained towards a different word. Previewing a plausible word benefited first-pass reading even when it was an unpredictable continuation of a highly constraining sentence frame. These findings suggest that older adults extracted semantic and syntactic information from parafoveal words as

effectively as young adults, regardless of its compatibility with contextually based expectancies.

With respect to Experiment 2's second aim of investigating age differences in the effects of (foveal) cloze predictability, older adults showed larger target predictability effects on several measures. However, these enhanced predictability effects were primarily due to older readers showing greater benefit for predictable targets, but no increased cost from processing unpredictable targets. Moreover, older adults' more efficient processing of predictable targets was principally due to reduced reanalysis, reflected in less rereading of the beginning of the sentence, and fewer regressions back to predictable targets than younger readers.⁵ This pattern of predictability effects is more consistent with increased efficiency in integrating predictable words into the sentence representation than with reliance on contextually based guessing. Such anticipatory prediction would be expected to manifest as increased skipping of predictable words, and increased *costs* on later fixation duration measures and regressions-in for unpredictable words that violate contextually generated guesses.

General Discussion

The present research examined older readers' parafoveal processing of contextually predictable and unpredictable words by measuring two forms of preview effects that have been robustly demonstrated in studies involving younger readers: preview benefits due to orthographic overlap between the preview and target words that are attributed to trans-saccadic integration (e.g., Cutter et al., 2015), and preview effects which depend on semantic and syntactic attributes of the preview stimulus itself, independently of its similarity to the

⁵ Interpretation of the Age $\times$ Predictability interactions is complicated by the fact that the preview was invalid on 75% of trials, which impacted target predictability effects more for younger readers than older readers. Although older readers showed numerically larger predictability effects than younger readers on a number of measures in the valid preview condition, the Age $\times$ Predictability interaction was not significant in a supplementary analysis of valid preview trials ($ts < 1.39$), presumably due to limited statistical power.

target. Specifically, we examined whether older readers are sensitive to the contextual plausibility of a parafoveal preview—a phenomenon that indexes both the efficiency of contextual processing, and the depth of parafoveal processing (Andrews & Veldre, 2019). Distinguishing between these two indices of parafoveal processing provides important new evidence relevant to evaluating competing explanations of how aging affects online reading.

The risky reading hypothesis proposed to account for age differences in patterns of eye movements during reading assumes that older adults compensate for age-related declines in visual acuity that reduce the efficiency of parafoveal processing by increasing their reliance on contextual prediction to “guess” the identity of upcoming words (Rayner et al., 2006). This view conflicts with the conclusions drawn from ERP studies of aging that older readers are slower and less effective at the contextual integration processes required to generate predictions about upcoming words (e.g., Wlotko et al., 2012). These contrasting views both predict that the plausibility preview benefit should be reduced or absent in older adults, for different reasons: either because of the reduced depth of parafoveal processing or because of reduced capacity for contextual integration. The present evidence that older adults are just as sensitive to the contextual plausibility of an upcoming parafoveal word as younger readers therefore appears incompatible with either account. Below, we consider the implications of this evidence for understanding the role of parafoveal information and contextual prediction in reading, and how they are modulated by age.

Parafoveal Processing in Reading

The first critical finding of this research is that conclusions about the impact of age on the extraction of information from the parafovea depend on what aspect of parafoveal processing is assessed. Our data confirmed previous findings that older adults benefit less than younger adults from identical or orthographically similar previews (Payne & Stine-Morrow, 2012; Rayner et al., 2010). Older readers showed a smaller preview validity effect

on multiple reading measures in both studies, and their orthographic preview benefit in Experiment 1 was significantly smaller than that shown by younger readers. Rayner et al. (2010) also found a smaller preview validity effect in older adults but it was restricted to later measures and due principally to a higher rate of refixations and reanalysis for targets preceded by invalid previews in younger than older readers. The invalid previews in the present experiments were all words and, therefore, orthographically legal while Rayner et al.'s (2010) invalid previews were illegal nonwords. The age differences that they observed may therefore reflect reduced cost from invalid previews for older adults, rather than reduced benefit from a valid preview. This smaller preview cost may reflect older readers' reduced sensitivity to display changes. In the present study, older participants were much less likely to report conscious awareness of display changes than young participants.⁶ While further research using more refined assessments of display-change detection (e.g., Slattery et al., 2011) is necessary to evaluate the contribution of conscious awareness of display changes, the present findings of age-related differences in trans-saccadic integration effects might be interpreted as confirming previous evidence that older readers are less effective at extracting information from the parafovea than younger readers.

However, this conclusion is difficult to reconcile with the robust plausibility preview effects shown by older readers in both experiments. In Experiment 1, older readers showed significant benefits to first-pass reading measures from previewing an unpredictable but contextually plausible word, regardless of its orthographic relatedness to the target. Experiment 2 replicated the plausibility preview effect in an independent set of materials, and demonstrated that it extended to contextually plausible words in sentence contexts that strongly predicted a different word. These findings provide clear evidence that older readers

⁶ Following the experiment, 21.5% of older adults (14/65) reported awareness of at least 1 display change compared to 55.5% of the combined young-adult sample (96/173).

processed the parafoveal preview sufficiently deeply to extract the semantic and syntactic information required to determine its plausibility in the sentence context (Veldre et al., 2020).

Thus, the two methods of indexing parafoveal processing yield contradictory conclusions. Older readers appear to show reduced parafoveal processing as indexed by preview benefits due to orthographic overlap. However, this is contradicted by evidence that older readers showed equivalent plausibility preview effects to younger readers, indicating that they successfully completed the deep parafoveal processing required to assess contextual fit.

One possible reconciliation of these apparently incompatible findings is that the plausibility preview effect does *not* require deep parafoveal processing. Rather than reflecting the outcome of semantic activation and post-lexical integration of parafoveal words, plausibility benefits may arise from a forward-going anticipatory prediction mechanism like that implemented in probabilistic models of the effects of contextual *predictability* (e.g., Levy, 2008; Staub, 2015). Such accounts assume that readers preactivate a *set* of words that form coherent continuations of a given context. Previewing a word from this set confers a benefit relative to an implausible word that has not been preactivated by context (Andrews & Veldre, 2019). If the initial activation of contextually plausible continuations occurs automatically, as assumed in memory models of sentence comprehension (e.g., Myers & O'Brien, 1998), older readers may show strong plausibility preview effects in tandem with reduced orthographic preview benefits because the former reflect an automatic contextual pre-activation mechanism that is unimpaired in older readers and does not require the trans-saccadic integration of foveal and parafoveal information that underpins the latter effects. Before elaborating on this selective age-related impairment, we discuss our predictability manipulations which provide further insight into how age modulates contextual prediction.

Aging and Predictability Effects

The global reading behavior of our older adults demonstrated the trade-off between rapid first-pass processing (longer forward saccades) and slower global reading (higher total sentence reading times and regressions) that has been attributed to a contextually based guessing strategy (Rayner et al., 2006). Such a guessing mechanism could potentially account for the increased skipping shown by older readers in both constraining and unconstraining sentence contexts. Depending on the relative timing of lexical processing and saccadic planning, increased guessing of the upcoming word_{N+1} would increase the probability that the reader would program a saccade to word_{N+2}, yielding a skip. Simulations of the *E-Z Reader* model (Reichle et al., 1998; Reichle et al., 2012) showed that incorporating a guessing mechanism provided the best fit to the empirical effects of aging on eye movements (McGowan & Reichle, 2018).

However, the assumption that this guessing mechanism is independent of the actual information available in the parafovea seems incompatible with the findings of Experiment 2. Older readers showed larger target predictability effects than younger readers on both the early measure of first-fixation duration and late measures of reading (go-past duration, regressions-out/in). Caution is required in interpreting the age interaction on first-fixation duration because it did not extend to the overlapping measures of single-fixation and gaze duration. However, age interactions were consistently observed on late go-past duration and regression measures that index integration processes suggesting that, compared to younger readers, older readers engaged in *less* reanalysis of predictable words. That is, older readers showed equivalent cost to younger readers when their predictions were disconfirmed but engaged in less rereading when the target was the expected predictable word. This is opposite to the pattern expected if older readers use previous context to guess upcoming words and conduct additional reanalysis processes when these guesses are violated (Rayner et al., 2006).

Rather, the older readers' enhanced predictability effects appear to reflect stronger commitment to their initial predictions if they are confirmed by early information extracted when the target is fixated, even if it conflicts with preprocessing of the parafoveal preview.

Thus, older readers benefited as much from highly predictable previews as younger readers and also showed an additional effect of the predictability of the foveal target word. This pattern of results mirrors Payne and Federmeier's (2017) ERP data from the RSVP-with-flankers paradigm in which younger and older adults showed similar parafoveal N400 predictability effects, but older adults showed substantially larger *foveal* N400 predictability effects. This was attributed to a specific age-related deficit in the integration of parafoveal and foveal information, due to normative declines in visual short-term sensory memory (e.g., Walsh & Thompson, 1978) and/or top-down attentional control (e.g., Madden, 2007). Such a deficit may also explain the attenuation of preview effects that depend on trans-saccadic integration observed in our older adults.

Foveal-Parafoveal Integration in Older Readers

The most critical outcome of the present research is the discrepant conclusions about older readers' capacity for parafoveal processing provided by the classic manipulations of preview-target orthographic overlap and the plausibility preview effect. Rather than reflecting impaired extraction of information from the parafovea, older adults' reduced sensitivity to orthographic overlap between the preview and target may reflect difficulties in integrating the outcomes of foveal and parafoveal processing. Such a view is potentially compatible with Staub and Goddard's (2019) extension of Norris's (2006) Bayesian Reader model to account for why target predictability effects in young-adult readers are eliminated by an invalid preview – an effect that was replicated by Veldre and Andrews' (2018b) young readers. Within Bayesian frameworks, contextual predictability influences the probability distribution for upcoming words and exerts its strongest influence when perceptual evidence is

ambiguous. Staub and Goddard (2019) argued that predictability does not influence fixation duration on targets preceded by invalid previews because identification of such stimuli can only begin when the word is in the high acuity region of foveal vision, where the strength of the perceptual evidence outweighs the influence of the prior probability distribution.

From this perspective, older adults do not rely more heavily on anticipatory prediction—they preactivate contextually appropriate continuations using similar automatic processes to those of young adults. However, their impaired ability to integrate parafoveal and foveal orthographic information reduces the influence of parafoveal preprocessing of the upcoming word on subsequent foveal word identification. In the boundary paradigm, where parafoveal information is often misleading, this is reflected in reduced disruption following an invalid preview and an increased influence of the predictability of the target word.

Reconciling Eye-Movement and ERP Evidence of Aging Effects

Finally, we consider the discrepancy between how age modulates predictability effects observed in eye-movement and ERP studies. The results of Experiment 2 converge with previous eye-movement studies in providing no evidence of older adults' reduced sensitivity to predictability consistently reported in ERP studies of the N400 (Wlotko et al., 2010). This age-related attenuation of N400 has been interpreted as indicating that many older adults are unable to achieve the rapid, incremental integrative processing required to generate anticipatory predictions during online reading. The present evidence that older adults' plausibility preview effects were indistinguishable from those of younger adults in two independent sets of stimuli challenges this claim. To demonstrate sensitivity to the contextual plausibility of a parafoveal word, older readers must have successfully integrated the earlier words of the sentence by the time they reached the pre-target word. The fact that older adults showed plausibility preview effects not only for the low constraint sentence frames of Experiment 1 but also for unexpected words in the high constraint sentences of

Experiment 2 implies that they effectively implement similar incremental integration mechanisms to those used by young adults. These findings converge with behavioral evidence of stronger contextual influences on word identification in older than younger adults (e.g., Speranza et al., 2000; Stine-Morrow et al., 2008).

Rather than indicating a “shift away from prediction” (Wlotko et al., 2012), age differences in ERP indices of prediction may reflect older adults’ difficulty adapting their automatic online reading processes to the demands of the RSVP task typically used in ERP studies of sentence processing (Choi et al., 2017). This procedure prevents readers from exerting volitional control over many aspects of natural reading behavior such as whether, and how long, to fixate a word, and deprive them of opportunities for both parafoveal processing and regressions to reread preceding context. Older adults may be particularly disrupted by this unusual format because it impedes application of the cognitive and oculomotor processes developed through reading experience to harness their rich verbal and world knowledge to compensate for their impoverished sensory capacities. The ability to self-regulate such processes may therefore be more critical to older adults’ reading strategies than it is for young adults.

Clearly, further research is required to identify the precise source of the differential impact of aging on predictability effects captured by eye movement and ERP methodologies. Recent methods for combining EEG and eye-movement recording will make an important contribution to this goal (e.g., Dimigen et al., 2011; Kretzschmar et al., 2015).

Conclusion

The present findings suggest that older readers are as effective as younger readers at generating graded predictions about upcoming words, and detecting their compatibility with information extracted from the parafovea. However, their reduced ability to integrate parafoveal and foveal representations limits effective use of information extracted from the

parafovea to support subsequent foveal word identification. Thus, to the extent that older adults engage in a reading strategy that trades off skipping and longer saccades against the need for rereading and reanalysis, it is a compensation for reduced visual short-term memory or attentional control rather than declines in higher level lexical or prediction processes. Indeed, the automaticity and efficiency of such processes may be enhanced by older adults' superior crystallized linguistic knowledge, at least under natural reading conditions, and support effective integration of bottom-up and top-down information despite declines in lower-level sensory and cognitive processes.

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Table 1

Means (and Standard Deviations) Scores on Tests of Written Language Proficiency for Older and Younger Adults in Experiment 2

Measure	Older adults	Younger adults	<i>t</i> (158)	<i>p</i>
ND Vocabulary (max 80)	65.89 (11.47)	46.58 (11.39)	10.50	<.001
ND Reading comprehension (max 76)	27.01 (11.76)	30.27 (11.75)	-1.72	.087
ND Reading rate (wpm)	294.95 (89.27)	273.48 (84.00)	1.53	.128
Spelling dictation (max 20)	15.08 (4.41)	11.23 (4.61)	5.27	<.001
Spelling recognition (max 88)	80.82 (4.98)	73.91 (7.80)	6.31	<.001
BIA – Verbal Comprehension (max 71)	59.83 (4.65)	-	-	-
BIA – Concept Formation (max 40)	30.68 (8.34)	-	-	-
BIA – Visual Matching (max 60)	45.52 (5.40)	-	-	-
Verbal Fluency – Phonemic	49.18 (13.21)	-	-	-
Verbal Fluency – Semantic	61.14 (11.39)	-	-	-

Note. Younger adults (*n*=95) from Veldre and Andrews (2018). ND = Nelson-Denny Reading Test administered with half the standard time limits for the vocabulary and reading comprehension subsections. BIA = Brief Intellectual Ability scores from Woodcock-Johnson Tests of Cognitive Abilities (not administered to younger adults). Verbal fluency scores are total number of words generated within specified time limit (not administered to younger adults).

Table 2*Mean (and Standard Deviation) Global Reading Measures for Older and Younger Adults*

Measure	Older adults	Younger adults
Total sentence reading time (ms)	5078 (1331)	4209 (1371)
Forward saccade length (letters)	7.76 (1.48)	7.37 (1.42)
Average fixation duration (ms)	214 (27)	218 (26)
Fixation count	14.99 (3.71)	15.19 (4.33)
Regression count	4.10 (1.77)	3.34 (1.98)

Note. Younger adults ($n=173$) from Veldre and Andrews (2017, 2018); means and SDs calculated per sentence.

Figure 1*Example of the Preview Manipulation used in Experiment 1*

- (a) The cupboard was full of filthy; rats because nobody had bothered to clean it.
 (b) The cupboard was full of filthy; rags because nobody had bothered to clean it.
 (c) The cupboard was full of filthy; rate because nobody had bothered to clean it.
 (d) The cupboard was full of filthy; junk because nobody had bothered to clean it.
 (e) The cupboard was full of filthy; sigh because nobody had bothered to clean it.

Note. Prior to the reader crossing the invisible boundary indicated by the dashed line, the preview of the target word *rats* was: (a) valid; (b) plausible neighbor; (c) implausible neighbor; (d) plausible unrelated; or (e) implausible unrelated. The comprehension probe associated with this item was: *The owner was probably very... 1) weary, 2) athletic, 3) unhygienic.*

Figure 2

Target Skipping Probability (Upper Panels) and Single Fixation Duration (Lower Panels) in each of the Preview Conditions in Experiment 1 for Younger and Older Readers. Error Bars are +/- SEM. See Text for Summary of Significant Effects.

Figure 3*Example of the Target Predictability and Preview Manipulation used in Experiment 2*

1. (a) The lawyer feared his client was probably| guilty when he was preparing the case.
 (b) The lawyer feared his client was probably| insane when he was preparing the case.
 (c) The lawyer feared his client was probably| courts when he was preparing the case.
 (d) The lawyer feared his client was probably| mirror when he was preparing the case.

2. (a) To reduce glare, they dimmed the bright| screen at the far end of the office.
 (b) To reduce glare, they dimmed the bright| lights at the far end of the office.
 (c) To reduce glare, they dimmed the bright| squint at the far end of the office.
 (d) To reduce glare, they dimmed the bright| honour at the far end of the office.

Note. Prior to the reader crossing the invisible boundary indicated by the dashed line, the preview of the target word was: (a) valid; (b) plausible; (c) implausible and contextually related; or (d) implausible and unrelated. In (1), the target word *guilty* is predictable and the plausible preview *insane* is unpredictable. In (2), the target word *screen* is unpredictable and the plausible preview *lights* is predictable.

Figure 4

Target Skipping Probability (Upper Panels) and Single Fixation Duration (Lower Panels) in each of the Preview Conditions in Experiment 2 for Younger and Older Readers. Error Bars are $\pm$ SEM. See Text for Summary of Significant Effects.

Note. The skipping analyses were based on preview contrasts averaged over target predictability because skipping occurs before the target is presented.

Figure 5
Target Predictability Effect (Averaged over Preview Conditions) on Target Fixation Duration (Left Panels) and Regression Measures (Right Panels) in Experiment 2 for Younger and Older Readers. Error Bars are +/- SEM.

Figure 6
Preview Validity Effect (Averaged over Target Predictability) across Target Fixation Duration Measures in Experiment 2 for Younger and Older Readers. Error Bars are +/- SEM.

Online Supplement for *Predictability Effects and Parafoveal Processing in Older Readers***by Aaron Veldre, Roslyn Wong, & Sally Andrews****Table S1**

Mean (and Standard Deviation) Reading Measures on the Target for Experiment 1 across Preview Conditions for Older Adults

Measure	Valid preview	Plausible Neighbor preview	Plausible Unrelated preview	Implausible Neighbor preview	Implausible Unrelated preview
<i>Fixation Duration Measures (ms)</i>					
First fixation	252 (29)	253 (32)	259 (26)	270 (31)	277 (31)
Single fixation	257 (33)	257 (33)	261 (26)	277 (35)	284 (37)
Gaze duration	269 (35)	276 (37)	284 (37)	300 (36)	316 (41)
Go-past duration	360 (81)	378 (80)	388 (97)	405 (98)	402 (73)
Total duration	392 (89)	431 (74)	432 (84)	433 (72)	435 (74)
<i>Fixation Probability Measures</i>					
Skipping	.26 (.12)	.26 (.12)	.29 (.14)	.27 (.12)	.24 (.12)
Regressions out	.19 (.13)	.20 (.14)	.20 (.12)	.22 (.13)	.21 (.14)
Regressions in	.23 (.10)	.29 (.18)	.30 (.16)	.24 (.13)	.24 (.11)

Table S2

Results of the (Generalized) Linear Mixed-Effects Models for Target Reading Measures for both Older Adults and Younger Adults in Experiment 1. Significant Effects are Indicated in Bold.

Measure	Fixed effect	<i>b</i>	<i>SE</i>	<i>t/z</i>
First fixation duration	Intercept	259.52	3.43	75.70
	Age	7.70	6.26	1.23
	Valid preview effect	-18.91	3.07	-6.16
	Plausibility preview effect	-16.34	2.82	-5.79
	Orthographic relatedness effect	-11.13	2.91	-3.83
	Plausibility × Relatedness	3.45	2.91	1.19
	Age × Valid preview effect	10.37	5.90	1.76
	Age × Plausibility preview effect	-2.06	5.45	-0.38
	Age × Relatedness preview effect	11.11	5.00	2.22
	Age × Plausibility × Relatedness	-0.24	5.35	-0.05
Single fixation duration	Intercept	265.17	3.92	67.62
	Age	5.15	7.13	0.72
	Valid preview effect	-21.68	3.46	-6.26
	Plausibility preview effect	-21.08	2.89	-7.29
	Orthographic relatedness effect	-13.03	3.47	-3.76
	Plausibility × Relatedness	3.87	3.36	1.15
	Age × Valid preview effect	14.44	6.55	2.21
	Age × Plausibility preview effect	-0.60	5.45	-0.11
	Age × Relatedness preview effect	16.03	5.81	2.76
	Age × Plausibility × Relatedness	-0.26	5.90	-0.04
Gaze duration	Intercept	290.91	4.84	60.14
	Age	-2.05	8.68	-0.24
	Valid preview effect	-32.73	4.19	-7.81
	Plausibility preview effect	-25.32	3.87	-6.54
	Orthographic relatedness effect	-17.46	3.90	-4.47
	Plausibility × Relatedness	4.19	3.78	1.11
	Age × Valid preview effect	14.60	7.86	1.86
	Age × Plausibility preview effect	-5.89	7.14	-0.83
	Age × Relatedness preview effect	10.96	6.92	1.59
	Age × Plausibility × Relatedness	5.94	6.99	0.85

Go-past duration	Intercept	371.25	8.47	43.81
	Age	33.15	14.95	2.22
	Valid preview effect	-53.37	6.69	-7.98
	Plausibility preview effect	-25.32	7.43	-3.41
	Orthographic relatedness effect	-22.44	7.21	-3.11
	Plausibility $\times$ Relatedness	6.35	6.74	0.94
	Age $\times$ Valid preview effect	33.50	13.29	2.52
	Age $\times$ Plausibility preview effect	11.55	13.08	0.88
	Age $\times$ Relatedness preview effect	37.38	12.53	2.98
	Age $\times$ Plausibility $\times$ Relatedness	-13.84	11.85	-1.17
Total duration	Intercept	436.11	14.56	29.95
	Age	-23.84	23.81	-1.00
	Valid preview effect	-53.40	8.64	-6.18
	Plausibility preview effect	6.50	7.32	0.89
	Orthographic relatedness effect	-12.19	7.26	-1.68
	Plausibility $\times$ Relatedness	-1.26	7.38	-0.17
	Age $\times$ Valid preview effect	28.50	16.51	1.73
	Age $\times$ Plausibility preview effect	-22.90	14.33	-1.60
	Age $\times$ Relatedness preview effect	12.89	12.72	1.01
	Age $\times$ Plausibility $\times$ Relatedness	9.30	14.34	0.65
Skipping	Intercept	-1.44	0.08	-17.64
	Age	0.43	0.15	2.87
	Valid preview effect	0.15	0.07	2.17
	Plausibility preview effect	0.27	0.07	3.89
	Orthographic relatedness effect	0.01	0.07	0.16
	Plausibility $\times$ Relatedness	-0.21	0.07	-3.04
	Age $\times$ Valid preview effect	-0.33	0.13	-2.50
	Age $\times$ Plausibility preview effect	-0.14	0.12	-1.20
	Age $\times$ Relatedness preview effect	0.05	0.12	0.41
	Age $\times$ Plausibility $\times$ Relatedness	-0.11	0.13	-0.90
Regressions out	Intercept	-1.73	0.09	-18.98
	Age	0.38	0.16	2.42
	Valid preview effect	-0.37	0.09	-3.91
	Plausibility preview effect	-0.15	0.08	-1.83
	Orthographic relatedness effect	-0.19	0.08	-2.43
	Plausibility $\times$ Relatedness	0.05	0.08	0.58
	Age $\times$ Valid preview effect	0.50	0.18	2.82
	Age $\times$ Plausibility preview effect	0.13	0.16	0.82
	Age $\times$ Relatedness preview effect	0.43	0.15	2.96
	Age $\times$ Plausibility $\times$ Relatedness	-0.11	0.15	-0.73

Regressions in	Intercept	-0.86	0.10	-9.05
	Age	-0.54	0.16	-3.44
	Valid preview effect	-0.21	0.08	-2.83
	Plausibility preview effect	0.36	0.07	5.37
	Orthographic relatedness effect	-0.05	0.07	-0.77
	Plausibility $\times$ Relatedness	-0.07	0.07	-1.09
	Age $\times$ Valid preview effect	-0.08	0.15	-0.51
	Age $\times$ Plausibility preview effect	-0.19	0.13	-1.46
	Age $\times$ Relatedness preview effect	-0.05	0.13	-0.42
	Age $\times$ Plausibility $\times$ Relatedness	0.14	0.13	1.10

Table S3

Results of the (Generalized) Linear Mixed-Effects Models for Target Reading Measures for Older Adults in Experiment 1. Significant Effects are Indicated in Bold.

Measure	Fixed effect	<i>b</i>	<i>SE</i>	<i>t/z</i>
First fixation duration	Intercept	263.38	5.09	51.76
	Valid preview effect	-13.87	4.41	-3.15
	Plausibility preview effect	-17.92	3.72	-4.81
	Orthographic relatedness effect	-5.89	4.24	-1.39
	Plausibility × Relatedness	3.46	3.72	0.93
Single fixation duration	Intercept	267.95	5.75	46.59
	Valid preview effect	-14.55	4.75	-3.07
	Plausibility preview effect	-21.67	3.82	-5.68
	Orthographic relatedness effect	-5.29	4.69	-1.13
	Plausibility × Relatedness	3.55	4.09	0.87
Gaze duration	Intercept	289.98	6.84	42.38
	Valid preview effect	-26.41	5.30	-4.98
	Plausibility preview effect	-27.97	5.27	-5.31
	Orthographic relatedness effect	-12.51	5.45	-2.30
	Plausibility × Relatedness	6.96	5.20	1.34
Go-past duration	Intercept	388.04	13.59	28.56
	Valid preview effect	-35.48	11.18	-3.17
	Plausibility preview effect	-19.78	11.92	-1.66
	Orthographic relatedness effect	-4.68	10.16	-0.46
	Plausibility × Relatedness	-0.38	12.01	-0.03
Total duration	Intercept	423.99	17.54	24.18
	Valid preview effect	-39.08	12.28	-3.18
	Plausibility preview effect	-3.17	10.21	-0.31
	Orthographic relatedness effect	-5.18	9.57	-0.54
	Plausibility × Relatedness	4.91	9.41	0.52
Skipping	Intercept	-1.16	0.11	-10.24
	Valid preview effect	-0.06	0.11	-0.53
	Plausibility preview effect	0.16	0.09	1.79
	Orthographic relatedness effect	0.03	0.09	0.34
	Plausibility × Relatedness	-0.27	0.11	-2.53

Regressions out	Intercept	-1.54	0.13	-12.03
	Valid preview effect	-0.15	0.14	-1.14
	Plausibility preview effect	-0.07	0.12	-0.53
	Orthographic relatedness effect	0.05	0.11	0.49
	Plausibility $\times$ Relatedness	-0.03	0.12	-0.22
Regressions in	Intercept	-1.11	0.09	-13.01
	Valid preview effect	-0.20	0.11	-1.78
	Plausibility preview effect	0.27	0.10	2.62
	Orthographic relatedness effect	-0.09	0.10	-0.86
	Plausibility $\times$ Relatedness	-0.01	0.11	-0.07

Figure S1

Target First Fixation Duration (Upper Panels), Go-Past Duration (Middle Panels), and Regression-out Probability (Lower Panels) in each of the Preview Conditions in Experiment 1 for Younger and Older Readers. Error Bars are +/- SEM.

Table S4*Mean (and Standard Deviation) Reading Measures on the Target for Experiment 2 across Preview Conditions for Older Adults*

	Predictable target				Unpredictable target			
	Predictable preview (Valid)	Unpredictable preview (Plausible)	Related preview (Implausible)	Unrelated preview (Implausible)	Unpredictable preview (Valid)	Predictable preview (Plausible)	Related preview (Implausible)	Unrelated preview (Implausible)
<i>Fixation duration measures (ms)</i>								
First fixation	220 (30)	241 (33)	255 (36)	256 (31)	237 (32)	225 (29)	266 (39)	263 (39)
Single fixation	222 (33)	245 (39)	258 (39)	263 (35)	238 (33)	225 (31)	268 (45)	271 (44)
Gaze duration	232 (41)	260 (43)	276 (36)	276 (36)	255 (39)	237 (32)	295 (47)	294 (43)
Go-past duration	279 (66)	329 (93)	343 (68)	366 (139)	345 (114)	296 (108)	394 (113)	375 (97)
Total duration	279 (81)	344 (82)	331 (79)	334 (63)	333 (65)	377 (117)	387 (70)	375 (70)
<i>Fixation probability measures</i>								
Skipping	.31 (.14)	.29 (.18)	.23 (.16)	.27 (.15)	.29 (.15)	.32 (.15)	.27 (.17)	.27 (.14)
Regressions out	.08 (.10)	.11 (.11)	.16 (.11)	.13 (.10)	.12 (.11)	.10 (.11)	.19 (.15)	.15 (.12)
Regressions in	.13 (.13)	.22 (.15)	.17 (.14)	.15 (.13)	.19 (.15)	.33 (.17)	.28 (.14)	.25 (.16)

Table S5

Results of the (Generalized) Linear Mixed-Effects Models for Target Reading Measures for both Older Adults and Younger Adults in Experiment 2. Significant Effects are Indicated in Bold.

Measure	Fixed effect	<i>b</i>	<i>SE</i>	<i>t/z</i>
First fixation duration	Intercept	247.23	3.41	72.42
	Age	-2.08	6.34	-0.33
	Target predictability	0.31	2.30	0.13
	Valid preview effect	-9.95	3.31	-3.00
	Plausibility preview effect	-26.70	3.46	-7.73
	Contextually related preview effect	-3.14	3.03	-1.04
	Age × Predictability	8.29	4.08	2.03
	Age × Valid PE	13.26	5.89	2.25
	Age × Plausibility PE	-2.36	5.83	-0.41
	Age × Related PE	10.30	5.93	1.74
	Predictability × Valid PE	30.98	5.37	5.77
	Predictability × Plausibility PE	-15.73	4.63	-3.40
	Predictability × Related PE	0.75	5.27	0.14
Single fixation duration	Intercept	250.83	3.60	69.59
	Age	-3.00	6.70	-0.45
	Target predictability	-1.04	2.51	-0.42
	Valid preview effect	-10.66	3.43	-3.11
	Plausibility preview effect	-30.70	3.92	-7.84
	Contextually related preview effect	-7.16	3.35	-2.14
	Age × Predictability	6.59	4.45	1.48
	Age × Valid PE	13.13	6.10	2.15
	Age × Plausibility PE	-0.01	6.52	0.00
	Age × Related PE	10.53	6.42	1.64
	Predictability × Valid PE	33.52	5.62	5.97
	Predictability × Plausibility PE	-16.37	4.92	-3.33
	Predictability × Related PE	-0.06	5.69	-0.01
Gaze duration	Intercept	271.95	4.20	64.74
	Age	-11.42	7.82	-1.46
	Target predictability	4.15	3.14	1.32
	Valid preview effect	-16.41	4.33	-3.79
	Plausibility preview effect	-32.44	4.52	-7.18
	Contextually related preview effect	-4.79	3.76	-1.27
	Age × Predictability	6.45	5.45	1.18

	Age $\times$ Valid PE	23.58	8.00	2.95
	Age $\times$ Plausibility PE	-7.72	7.85	-0.98
	Age $\times$ Related PE	9.90	7.27	1.36
	Predictability $\times$ Valid PE	43.87	6.81	6.44
	Predictability $\times$ Plausibility PE	-28.83	5.87	-4.91
	Predictability $\times$ Related PE	0.96	6.67	0.15
Go-past duration	Intercept	345.15	8.27	41.74
	Age	-8.79	14.98	-0.59
	Target predictability	15.79	5.59	2.83
	Valid preview effect	-18.47	8.69	-2.13
	Plausibility preview effect	-54.31	7.63	-7.12
	Contextually related preview effect	-3.46	7.25	-0.48
	Age $\times$ Predictability	23.67	10.40	2.28
	Age $\times$ Valid PE	40.92	16.69	2.45
	Age $\times$ Plausibility PE	4.24	14.83	0.29
	Age $\times$ Related PE	6.31	14.32	0.44
	Predictability $\times$ Valid PE	79.84	13.31	6.00
	Predictability $\times$ Plausibility PE	-51.02	11.46	-4.45
	Predictability $\times$ Related PE	4.70	13.03	0.36
Total duration	Intercept	355.46	8.83	40.24
	Age	-20.75	16.17	-1.28
	Target predictability	37.28	6.64	5.62
	Valid preview effect	-72.50	8.75	-8.29
	Plausibility preview effect	3.30	6.51	0.51
	Contextually related preview effect	3.76	6.65	0.56
	Age $\times$ Predictability	14.72	10.24	1.44
	Age $\times$ Valid PE	42.11	16.55	2.54
	Age $\times$ Plausibility PE	1.92	11.24	0.17
	Age $\times$ Related PE	-0.84	12.01	-0.07
	Predictability $\times$ Valid PE	28.59	11.47	2.49
	Predictability $\times$ Plausibility PE	-7.36	9.81	-0.75
	Predictability $\times$ Related PE	-0.16	11.19	-0.01
Skipping	Intercept	-1.27	0.09	-14.29
	Age	0.39	0.12	3.20
	Predictable vs. Unpredictable	0.26	0.08	3.37
	Plausible vs. Implausible	0.35	0.06	6.27
	Implausible related vs. unrelated	0.00	0.08	-0.03
	Age $\times$ Predictable preview	-0.09	0.13	-0.68
	Age $\times$ Plausible preview	-0.21	0.10	-2.02
	Age $\times$ Implausible related preview	-0.25	0.15	-1.73

Regressions out	Intercept	-1.80	0.10	-18.82
	Age	0.14	0.16	0.90
	Target predictability	0.08	0.07	1.17
	Valid preview effect	-0.06	0.11	-0.57
	Plausibility preview effect	-0.52	0.09	-5.59
	Contextually related preview effect	0.14	0.10	1.46
	Age $\times$ Predictability	0.34	0.13	2.56
	Age $\times$ Valid PE	0.05	0.22	0.21
	Age $\times$ Plausibility PE	0.22	0.18	1.25
	Age $\times$ Related PE	0.12	0.18	0.67
	Predictability $\times$ Valid PE	0.76	0.20	3.79
	Predictability $\times$ Plausibility PE	-0.36	0.16	-2.25
	Predictability $\times$ Related PE	0.13	0.16	0.82
Regressions in	Intercept	-1.26	0.07	-17.27
	Age	-0.31	0.14	-2.20
	Target predictability	0.44	0.06	6.87
	Valid preview effect	-0.78	0.08	-10.04
	Plausibility preview effect	0.27	0.07	4.03
	Contextually related preview effect	0.18	0.08	2.18
	Age $\times$ Predictability	0.26	0.11	2.51
	Age $\times$ Valid PE	0.15	0.14	1.04
	Age $\times$ Plausibility PE	0.09	0.12	0.73
	Age $\times$ Related PE	-0.07	0.14	-0.51
	Predictability $\times$ Valid PE	-0.11	0.14	-0.77
	Predictability $\times$ Plausibility PE	0.13	0.11	1.13
	Predictability $\times$ Related PE	-0.08	0.13	-0.62

Table S6

Results of the (Generalized) Linear Mixed-Effects Models for Target Reading Measures for Older Adults in Experiment 2. Significant Effects are Indicated in Bold.

Measure	Fixed effect	<i>b</i>	<i>SE</i>	<i>t/z</i>
First fixation duration	Intercept	246.21	4.47	55.06
	Target predictability	4.65	2.76	1.68
	Valid preview effect	-3.79	4.21	-0.90
	Plausibility preview effect	-27.48	4.15	-6.63
	Contextually related preview effect	1.95	4.26	0.46
	Predictability × Valid PE	34.38	7.52	4.57
	Predictability × Plausibility PE	-23.00	6.53	-3.52
	Predictability × Related PE	9.34	7.48	1.25
Single fixation duration	Intercept	249.35	4.78	52.22
	Target predictability	2.49	2.85	0.88
	Valid preview effect	-4.64	4.33	-1.07
	Plausibility preview effect	-30.11	4.72	-6.38
	Contextually related preview effect	-1.57	4.31	-0.36
	Predictability × Valid PE	35.67	7.77	4.59
	Predictability × Plausibility PE	-26.03	6.81	-3.82
	Predictability × Related PE	7.29	7.90	0.92
Gaze duration	Intercept	266.14	5.28	50.41
	Target predictability	7.41	3.56	2.08
	Valid preview effect	-5.29	5.22	-1.01
	Plausibility preview effect	-35.62	5.03	-7.09
	Contextually related preview effect	-0.62	5.29	-0.12
	Predictability × Valid PE	45.40	9.06	5.01
	Predictability × Plausibility PE	-38.10	7.86	-4.85
	Predictability × Related PE	-1.00	9.01	-0.11
Go-past duration	Intercept	340.18	10.30	33.02
	Target predictability	27.91	8.61	3.24
	Valid preview effect	3.56	12.91	0.28
	Plausibility preview effect	-53.24	9.98	-5.34
	Contextually related preview effect	-0.44	11.42	-0.04
	Predictability × Valid PE	94.66	20.53	4.61
	Predictability × Plausibility PE	-66.32	17.79	-3.73
	Predictability × Related PE	16.58	20.44	0.81

Total duration	Intercept	345.23	11.20	30.84
	Target predictability	43.61	9.72	4.49
	Valid preview effect	-51.81	10.71	-4.84
	Plausibility preview effect	4.02	8.99	0.45
	Contextually related preview effect	3.31	9.03	0.37
	Predictability $\times$ Valid PE	26.68	17.31	1.54
	Predictability $\times$ Plausibility PE	-12.11	14.88	-0.81
	Predictability $\times$ Related PE	1.39	17.01	0.08
Skipping	Intercept	-1.06	0.11	-9.93
	Predictable vs. Unpredictable	0.19	0.11	1.78
	Plausible vs. Implausible	0.24	0.07	3.26
	Implausible related vs. unrelated	-0.15	0.11	-1.39
Regressions out	Intercept	-1.70	0.13	-13.41
	Target predictability	0.23	0.11	2.05
	Valid preview effect	-0.01	0.18	-0.06
	Plausibility preview effect	-0.36	0.16	-2.33
	Contextually related preview effect	0.17	0.17	1.04
	Predictability $\times$ Valid PE	0.49	0.31	1.58
	Predictability $\times$ Plausibility PE	-0.28	0.26	-1.10
	Predictability $\times$ Related PE	0.03	0.28	0.10
Regressions in	Intercept	-1.40	0.08	-17.63
	Target predictability	0.58	0.10	5.66
	Valid preview effect	-0.73	0.13	-5.74
	Plausibility preview effect	0.35	0.10	3.54
	Contextually related preview effect	0.13	0.12	1.09
	Predictability $\times$ Valid PE	-0.07	0.22	-0.30
	Predictability $\times$ Plausibility PE	-0.10	0.18	-0.53
	Predictability $\times$ Related PE	-0.11	0.22	-0.50